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FLOOD TIDE IN ILLINOIS

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Flood Tide in Illinois

By Frederick Squires*

Introduction

This article gives the highlights on three applied water-floods now operating in Illinois oil pools, points out earlier conditions which encouraged

their application, and suggests territory favorable for water-flooding. It proposes a method of flooding certain old territory, without redrilling, and recommends flooding in the early life of certain pools.

Three Contrasting Floods

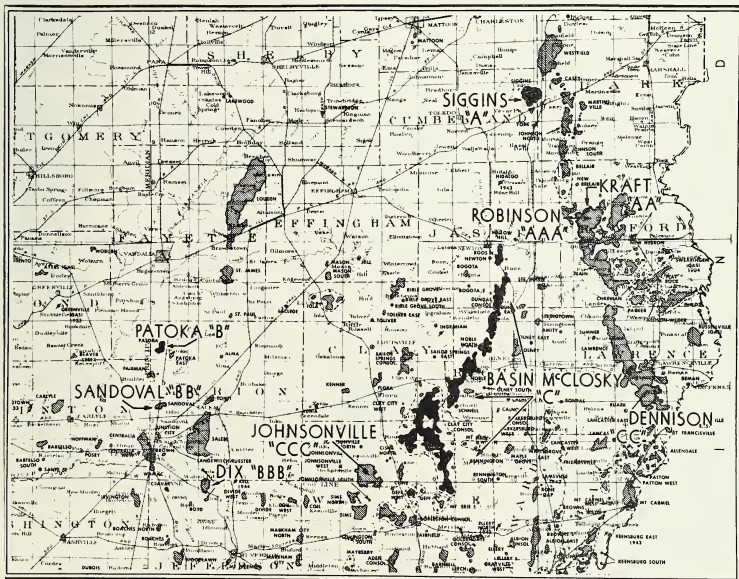
The three areas being flooded are shown in figure 1. These three operations are on sands of different ages and depths. They vary in the distances between wells and in the kind of water used. The only similarity is their success.

Highest in the geologic column is the Siggins flood, operated by the Forest Oil

Corporation on a Pennsylvanian sand. Lower is the Patoka flood, conducted by the Belmont Corporation and the Sohio Oil Company on the Bethel sand, and last is the McClosky flood, operated by the Pure Oil Company on their extensive McClosky lime holdings. These three floods work on the state's productive sands of greatest areal extent.

The Siggins Operation

Under an agreement between the Ohio Oil Company and the Forest Oil Corporation, a flood was undertaken by the latter in the Siggins pool in Union Township, Cumberland County, and



KEY MAP SHOWING LOCATIONS OF
SIGGINS, PATOKA, AND McCLOSKEY FLOODS

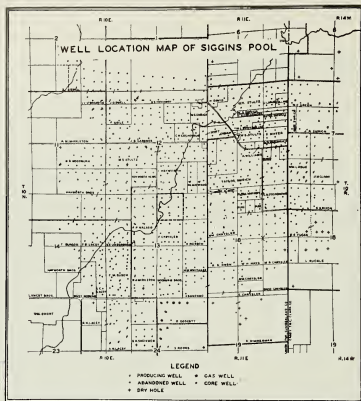


Fig. 2. Well location map of the Siggins pool. This shows at A in figure 1.

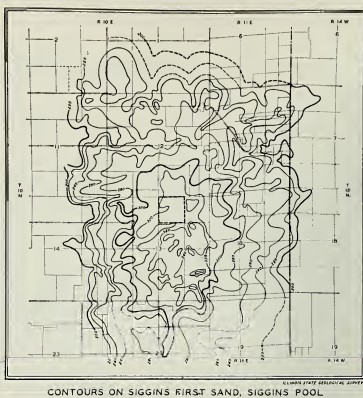


Fig. 3. Contours on Siggins first sand, Siggins pool. Square near the center shows the location of the No. 2 flood. This is at the top of the structure, (Bull. 54, Pl. XXVII)

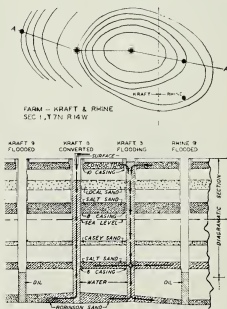


Fig. 5. Section and plan of Kraft flood. This was the first applied flood in Illinois. It made use of salt water injected from the surface as a flooding medium. It is the predecessor in Pennsylvania sand to the Siggins operation. AA on figure 1 shows its location.

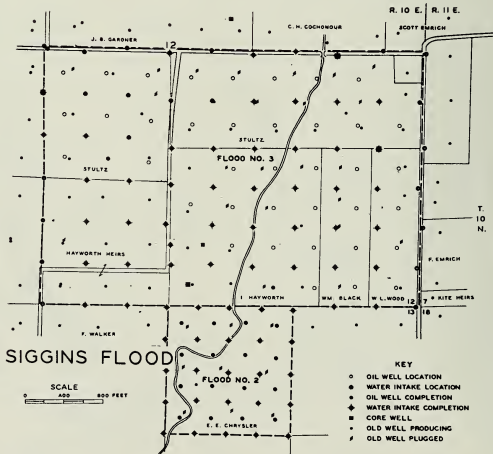
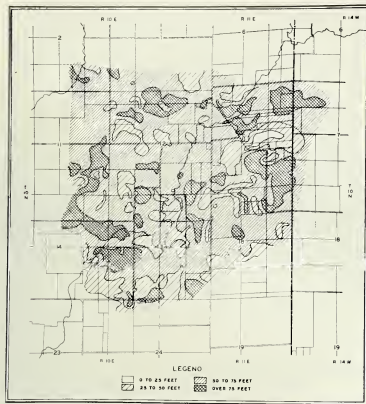


Fig. 4. Plan of the Siggins floods No. 2 and No. 3. Note the complete redrilling and close spacing of the No. 2 flood compared with the wider spacing and the drilling of input wells only in the No. 3 flood.

Fig. 1. The single letters on solid black territory indicate the present active floods, the double letters refer to earlier floods shown in detail in figures 5, 14, and 15 and the triple letters designate territory favorable for future expansion.



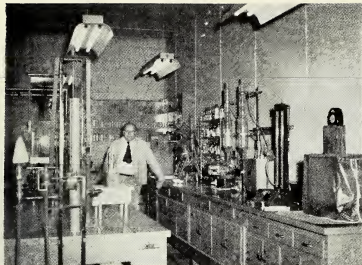


Fig. 11. Laboratory for Siggins operation. This is located near the Forest Oil Corporation office at Casey, Ill. It is well equipped and operations in it follow all drilling in great detail. Paul Philippi, the company's technician, is shown.

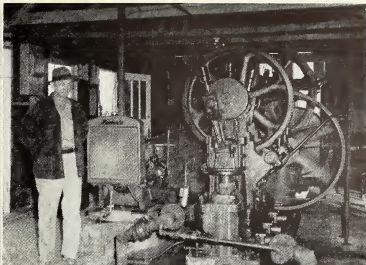
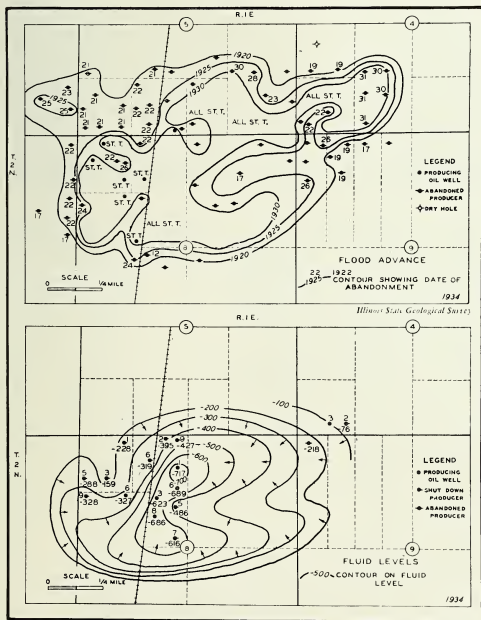


Fig. 12. Booster pump for Siggins operation. Water is delivered to the pump from the source well pump and raised by it to the desired input pressure.



NATURAL WATER ENCROACHMENT AND DIRECTION, SANDOVAL POOL

the south part of the No. 2 flood started in an area of relatively thin sand and that it and the No. 3 flood moved into areas of thicker and richer pay. Response to flooding closely followed these changing conditions.

Figure 7 shows initial well productions in the Siggins area.

In general, the best response to water-flooding corresponds to areas of greatest cumulative natural production (fig. 8). It is interesting to note that all this evidence agrees with findings made from core analyses and therefore would have been, even without core information, a reliable guide in the choice of the Siggins pool for flooding.

Figure 9 shows a series of permeability profiles, made for the most part from examinations of sand chips. They show high permeabilities and considerable variation from top to bottom. The operators use these profiles, also, as a guide in the location of packers. These high permeabilities prove that the extension of the well spacing for the No. 3 flood was logical.

Figure 10 shows the above-ground intake-well assembly. Oil content was determined in some cases by colorimetric analyses. After selective shooting, caliper runs have been made to determine changes in well-bore profiles in order to find out to what extent the heavy shooting of dense sections increased their circumference over unshot or lightly shot open sections and in order to equalize water inlet. The greatest diameter obtained was 30 inches.

Figure 11 is a photograph of the com-

Fig. 13. Natural water encroachment and direction, Sandoval pool. This area shows at BB in fig. 1. Sandoval is a neighbor and produces from the same Bethel sand as Patoka. From the results of water encroachment on oil production an argument in favor of flooding Patoka was presented. (Ill. Geol. Survey Rept. Inv. no. 89, fig. 42 p. 57)

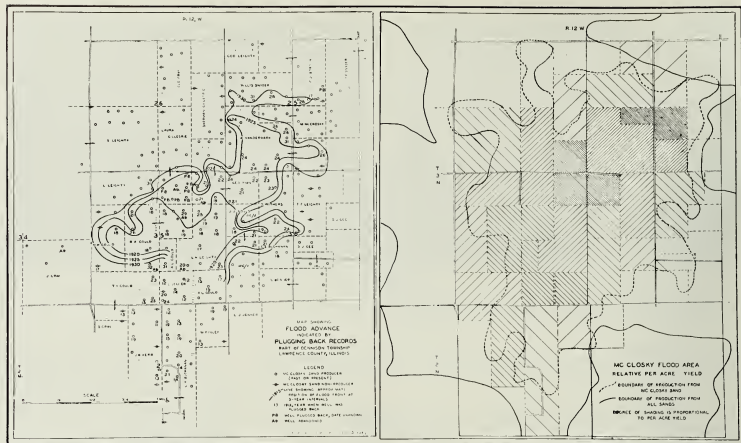


Fig. 14. Maps showing natural flood advance and enrichment of Dennison flood. This territory is shown also at CC figure 1. Water advanced from the southwest toward the northeast as shown by the contours and enriched each farm in its path with oil accumulated before. It demonstrates that pumping wells at the front edge of a flood may be by-passed by oil and is an argument in favor of five-spotting. (Ill. Geol. Survey Rept. Inv. No. 89, figure 27, p. 42, and figure 30, p. 45)

pany laboratory, and figure 12 is a photograph of the booster plant. Water is obtained from a well in the glacial drift in the valley of Hurricane Creek, pumped six miles through 6-inch pipe and boosted at the property by this pump to the desired input pressure. Untreated and unfiltered water has proved satisfactory because the system is entirely closed against oxidation, and the water is filtered by the gravel from which it is pumped.

The Screening Test

The success of the No. 3 flood will start a hunt for favorable producing strata on which to extend the process. In order to reduce the chances of failure, a screening test must be applied to Pennsylvanian and all other producing strata. Territory producing large quantities of water must be eliminated. Two operations in Illinois, one on sand which produced water from the day the first well was drilled and the other on sand which had become water-logged through badly abandoned wells, have been disappointing.

A second rule is to select rich territory. Richness can be checked by core analysis, by lease history, and by a combination of both. Figures 6, 7, and 8 give such a lease history for the Siggins field.

A study of a new field, by applying the tests shown in these drawings for the Siggins pool, provides a good screening test when supplemented by a determination of oil-water ratios from the wells under consideration. A permeability test, by electric logging of old wells, will greatly help this screening test. Core analyses and oil production during flooding at Siggins have corroborated deductions made from preliminary screening.

Parts of the North Johnson pool, the first sand at Bellair (the Sussanah Smith Farm for example) as well as the New Hebron area, large parts of Oblong and Martin Townships in Crawford County that produce from the Robinson sand, and parts of the old Allendale field in Wabash County would stand up under such screening tests. Many areas in the new fields, no doubt, will do the same.

The Patoka Operation†

The wells included in the Patoka flood are located in Secs. 20, 21, 28, and 29, T. 4 N., R. 1 E., Marion County, Illinois, near the town of Patoka, from which the pool takes its name.

Test-flooding was done at the north end of the field, in Sec. 21, the successful results of which led to a campaign in 1944 to drill intake wells and to flood

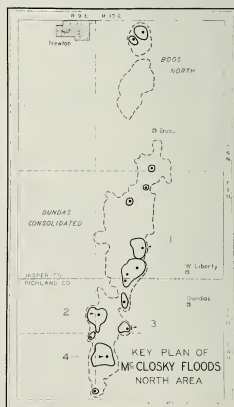


Fig. 15. Key plan of McClosky floods north area. Pools numbered on this plan are shown in detail in figure 17.

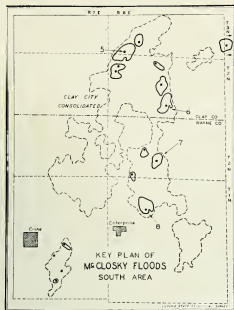


Fig. 16. Key plan of McClosky floods south area. Pools numbered on this plan are shown in detail in figure 17.

the whole area. The sand is the Bethel which occurs here at a depth of about 1,400 feet. It is the same sand as that producing in the nearby Sandoval pool, which was flooded successfully by edge-water encroachment (fig. 13). The most striking feature of the operation is the long spacing of 660 feet from intake well to intake well and from producer to producer. This can be compared with the Siggins No. 2 flood, where the spac-

ing was 330 feet, and with the Siggins No. 3 flood, where the spacing was 440 feet.

The injection water is Tar Springs salt water, which is pumped from two wells, aerated, chemically treated and filtered. This procedure is in contrast to the Siggins operation, which uses untreated and unfiltered fresh water.

The Patoka pool has been a pioneer in several ways: It was one of the first structures in the state to be located by seismograph, rotary drilling found its first Illinois application there, and it was the first to use wide well spacing and salt water for flooding.

The Bethel sand, on which this Patoka flood operates, is especially adapted to water injection. It has responded to water encroachment at Sandoval and St. Francisville and to accidental flooding from upper water on the Johnson farm in northern Lawrence County. Such Bethel sand pools as Dix are extremely promising.

The (Cypress) Kirkwood wells of the old Lawrence County field produced from about the same depth as the Bethel sand at Patoka; they are spaced 9 wells to the 40-acres; the producing sand covers large areas with a thick uniform sand body; and the area has been unusually rich and free from water. The large initial productions of the wells indicate high sand permeability. All

these factors favor flooding. The deductions from them are reinforced by the record production due to accidental flooding of wells on the Combs and Smith farms and by increased production due to water encroachment at Oakland City.

McClosky Operation

The third flooding process has taken place on McClosky lime in areas marked "Basin McClosky" on the general plan. It covers pools which are owned almost entirely by the Pure Oil Company, the block being so complete that it amounts to a unit operation with all the advantages of such a layout.

Nature taught the lesson. The McClosky natural water encroachments in Dennison and Petty Townships, Lawrence County (fig. 14),⁸ showed that water moved large quantities of oil and that permeable horizons were continuous over wide areas.

Flooding the McClosky was recommended by the Illinois Geological Survey in 1937 in Circular 23, "Contributions of the Fifth Annual Mineral Industries Conference," October 9, 1937, "Recent Developments in Water Flooding in Illinois Oil Fields," by Frederick Squires, page 123:

"Flood characteristics of the McClosky are these: Water travels fast, oil production is always benefitted. Only part of the area has been flooded. Therefore

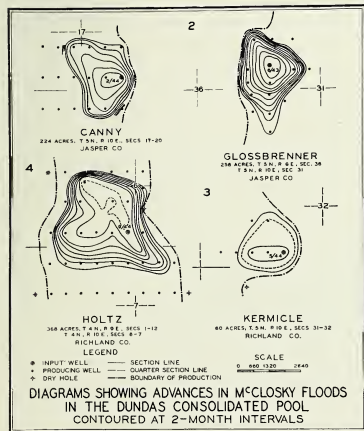


Fig. 17. Diagrams showing advances in McClosky floods in the Dundas consolidated pool, contoured at two-month intervals. The contour line represents the front of the oil flood.

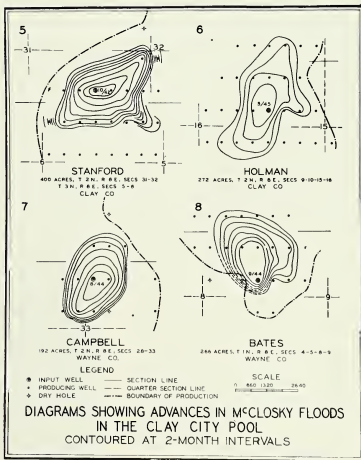


Fig. 18. Diagrams showing advances in McClosky floods in the Clay City Consolidated pool, contoured at two-month intervals.

the obvious deductions are: (1) That the remaining McClosky should be intentionally flooded; (2) that this can be done without new drilling, by using alternate wells for flooding and pumping; and (3) that recoveries, if at all like natural floods, will amount to millions."

The Pure Oil Co. has started a series of floods shown in figures 15 and 16. They are using 32 old wells as input wells and produce from other old wells. The Basin McClosky was drilled in general with one well to 20 acres, although smaller areas had one well to 10 acres and still smaller tracts, drilled after Pearl Harbor, had one well to 40 acres. It is obvious from the map that almost all the 20-acre patterns have unequal distances, either 1,320 or 660 feet, between adjoining wells. The 10-acre pattern is a uniform 660-foot spacing, and the 40-acre pattern a uniform 1,320-foot spacing.

Water for the earliest injection in the southern end of the tract was obtained from the Pure's Little Wabash River pumping station. It was used without treatment and only a small amount of filtering. The McClosky lime is so open that nothing plugs it, making chemical treatment unnecessary. It should be remarked here that the areas under flood had reached their economic limit of yield under primary recovery methods before resorting to this secondary process. In later installations, the casing in input wells was perforated opposite the water-bearing Cypress, which flooded the McClosky under natural head. Twenty-eight separate floods have affected more than 3,800 acres to a greater or lesser degree.

Large volumes of water were used. The speed and direction of water advance has varied as shown by the dated contours surrounding each input well (figs. 17 and 18). Invasion is extremely rapid.

An oil production graph is given for two adjoining wells, shown here as figure 19. They are the first and second locations from the water-input well. The second location is usually more productive as is shown here.

The total oil production obtained to date from the 3,800 acres affected indicates that the production from all the McClosky acreage shown on the two McClosky maps will be very great when subjected to flooding.

Judging by the success already achieved in flooding the McClosky sand, a large proportion of the remaining territory will respond favorably. Such pools as Johnsonville seem certain to succeed.

The method now in use may be improved after longer experience. Five-spot well spacing and line flooding may be tried and the results compared, in-

sofar as possible, with the circle floods now in operation.

Input water from the Cypress sand or other upper sands may be metered and regulated as conditions require. If and when new McClosky pools are found, the probability of later flooding should influence the location of wells. Certainly neighboring wells should be equidistant. A glance at figures 17 and 18 shows that permeabilities, always high, vary widely. A 40-acre spacing should work in such areas as 3 and 6 (on figs. 17 and 18). After developing on 40-acre spacing and noting the permeabilities encountered, closer spacing would be possible if necessary.

The next question to arise would be the time to flood. Reservoir pressure could be maintained by flooding as soon as the field was outlined. This would be a logical procedure.

Summary

The one thing that these three floods have in common is success (fig. 20).

They vary in every other important respect—the sands, the flooding water, the age of the wells, the well spacing, and the number of new wells required (fig. 21). This is in striking contrast to flooding in Pennsylvania, New York, Kansas, and Oklahoma, where the operations have a much greater similarity. Experience gained in these fields cannot be applied to all the problems in Illinois, where each sand is a law unto itself. The principal difference between Illinois sands and out-of-state sands is permeability. The average high permeabilities for 50 wells each was 545 millidarcies for the Cypress, 221 for the Bethel, and 1,858 for the McClosky. Inasmuch as degree of permeability determines well spacing, Illinois sands with their greater permeability permit wider well spacing than do out-of-state sands, as is demonstrated in the spacing in the three fields just discussed. The Siggins No. 2 flood started with 330 feet between like wells (the Bradford technique); the

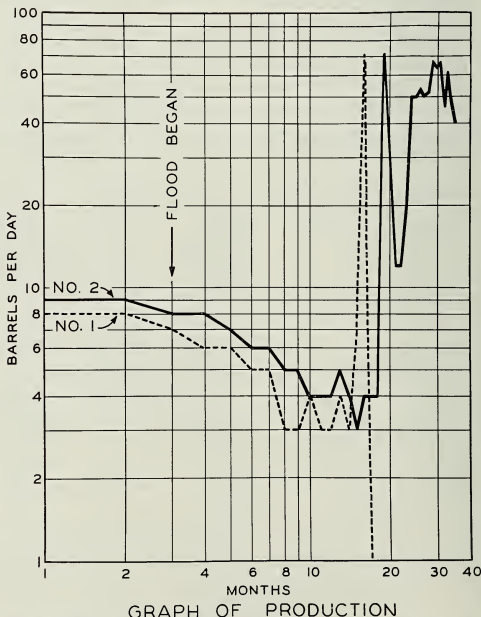


Fig. 19. Graph of Production McClosky flooded wells. This shows the typical condition wherein the second well from the flooding well gives a better account of itself than the nearer well reached by water first. It may be an argument in favor of five-spotting or at least counter pressure floods.

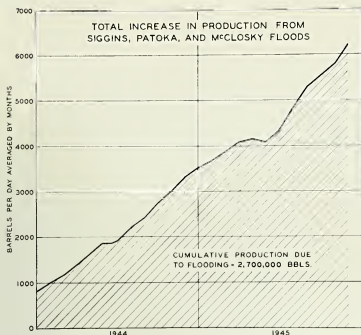


Fig. 20. Total increase in production from Siggins, Patoka and McClosky floods. It includes the production for twenty-three months. All the properties are increasing.

Siggins No. 3 increased this amount to 440 feet; Patoka went to 660 feet; and the Basin McClosky expanded it to an average of 1,000 feet.

By these figures it is demonstrated that the permeability of some oil sands in Illinois is so great that the minimum well spacing could be the same as (or greater than) the standard old field spacing of 400-440 feet. Therefore, such old fields can be flooded without re-drilling but by using old wells only. Large areas of the Cypress, Bethel, and McClosky sands of the old fields come into this category. When their permeabilities would permit spacing wider than 440 feet between like wells, the only effect of using old wells is that their

spacing, which is closer than is necessary, makes for a quicker clean up.

The early belief was that flooding should be applied only in the old age of wells, like those in the Siggins sand. The wells in the Patoka and McClosky floods are comparatively young; yet together they show even better results in flood production and have a far greater salvage value. The logical step appears to be to flood, or to conjointly repressure and flood most fields soon after drilling, and to flow the wells from start to finish.

Engineering Problems Involved

The petroleum engineer should be encouraged to reinvestigate, since a rule need not be true just because it is old.

DIAGRAM SHOWING SOURCES OF FLOODING WATER

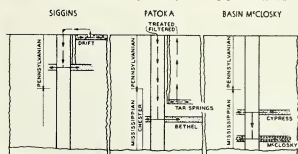


DIAGRAM SHOWING RELATIVE DISTANCES WELL TO WELL

Fig. 21. Diagram showing sources of flooding water and diagram showing relative distances well to well for the Siggins, Patoka and McClosky floods. The noteworthy aspect of this drawing is the difference in every case. These three floods have demonstrated the probability of success in flooding the three most widespread sands in Illinois.

Bradford sands were once thought floodable only because they were tight. Now they are believed to be floodable in spite of their tightness. Illinois flooding presents many new problems, some of which are listed below.

A meter should be provided for measuring and a valve for regulating the water which leaves an upper sand to flood a lower sand. Both devices should record above ground.

A side-wall sampler should be designed to operate in shot holes in order to get permeability test samples from old wells and to aid in screening them for flooding.

Permeability should also be determined in the well itself. The weakest spot in any screening method is the lack of permeability data. Without it, there is no sure measure for well spacing. Without it, there is no sure way of telling whether old wells, without new drilling, may be flooded out within an economic time limit.

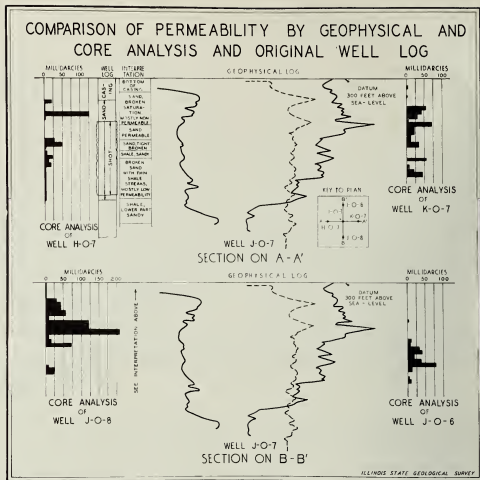
Permeability information might be determined in old wells by measuring fluid injections as the sand bore is filled up, foot by foot, with a removable seal. It might be obtained also by measuring the intake rates of two liquids of different conductivity under equal pressure when the interface is located by an electric pilot. Permeability to liquids might be computable from the results of tests on permeabilities to gases entering uniformly reduced sections of producing sand.

The use of alkaline flooding water was mentioned in a patent 1,238,355 issued to me many years ago. The method was tried only on sands, where it was



Fig. 22. The mobile laboratory, with instruments from which the permeability logging of the Siggins well was made.

a failure, probably due to its action on clay. Alkaline water gives astonishingly good sand-washing results on small specimens in the laboratory but dismal failures in the field whenever clay is present in the sand. It should be demonstrated by field test whether or not the McClosky lime, which is always free from clay, will permit more successful flooding with alkaline than with neutral water.



ure 22 shows the mobile laboratory in the background and the well logging equipment at the well. Figure 23 shows the geophysical log by C. A. Bays, and for comparison, permeabilities obtained from cores taken from neighboring wells and from the drilling log of the well itself.

Conclusion

mon goal of success. They cover only a small proportion of the area of the sands on which they operate and a far tinier fraction of the total area of the sands of Illinois. Each flood has proved to be a separate problem, for the solution of which out-of-state operations present little precedent. A tremendous opportunity for expansion lies ahead of the petroleum engineer.